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Assessing the impact of climate change on Columbia River Basin agriculture through integrated crop systems, hydrologic, and water management modeling

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Introduction

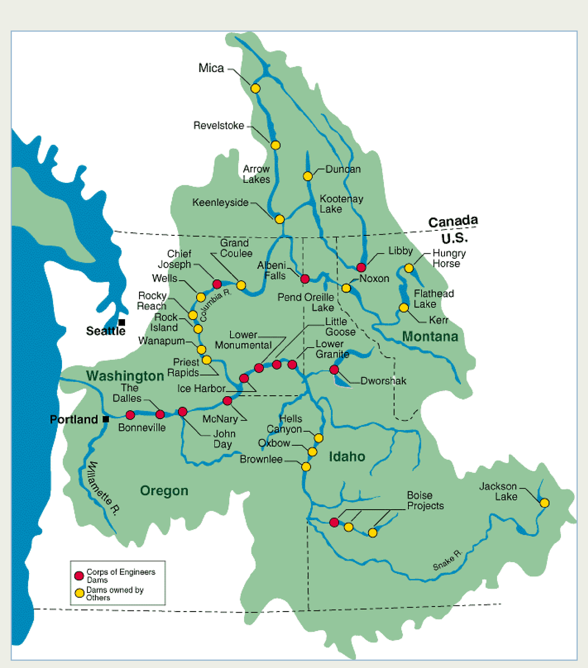
- ❑ Rising temperature and changes in the frequency and magnitude of precipitation events due to climate change (IPCC-AR4 report) are anticipated to affect crop production, water availability and quality, and flood risk in the PNW (Stockle et al 2009, Elsner et al 2009, Hamlet and Lettenmaier 2007).
- ❑ Agriculture is a vital part of the economy in the Pacific Northwest (PNW) , with an annual value over $5 billion in Washington State alone. In 2008, PNW wheat production alone accounted for $1.7 billion, the third largest value in the United States (NASS, 2009) .
- ❑ The eastern side of the Cascade Mountains, which receives only 5-25" of rain annually, is particularly vulnerable to drought. In the last decade, there have been 10-20% yield losses during severe drought years, with an average of $90 million/year (NASS, 2009).
- ❑ The challenge is to anticipate the probable effects of climate change on the hydrological cycle and make sound land use, water use, and agricultural management decisions that will best serve the needs of agricultural production while protecting our freshwater resources.

Objective

- ❑ To apply an integrated modeling framework (coupled hydrology and cropping systems model, reservoir model and economics model) to study future (2030s decade) water supply and irrigation water demand over the Columbia River Basin for improved water resources management.

Basin Description

- ❑ The Columbia River Basin in the Pacific Northwest has a drainage area of about 670,000 square kilometers covering all or parts of seven states in the US as well as British Columbia.
- ❑ Water resources are managed to meet several competing demands including hydropower generation, irrigation, navigation, recreation, and fish flows.
- ❑ Irrigated agriculture is an important part of the economy. Crops of high economic value like tree fruits, wine grapes and hops are grown in the region.

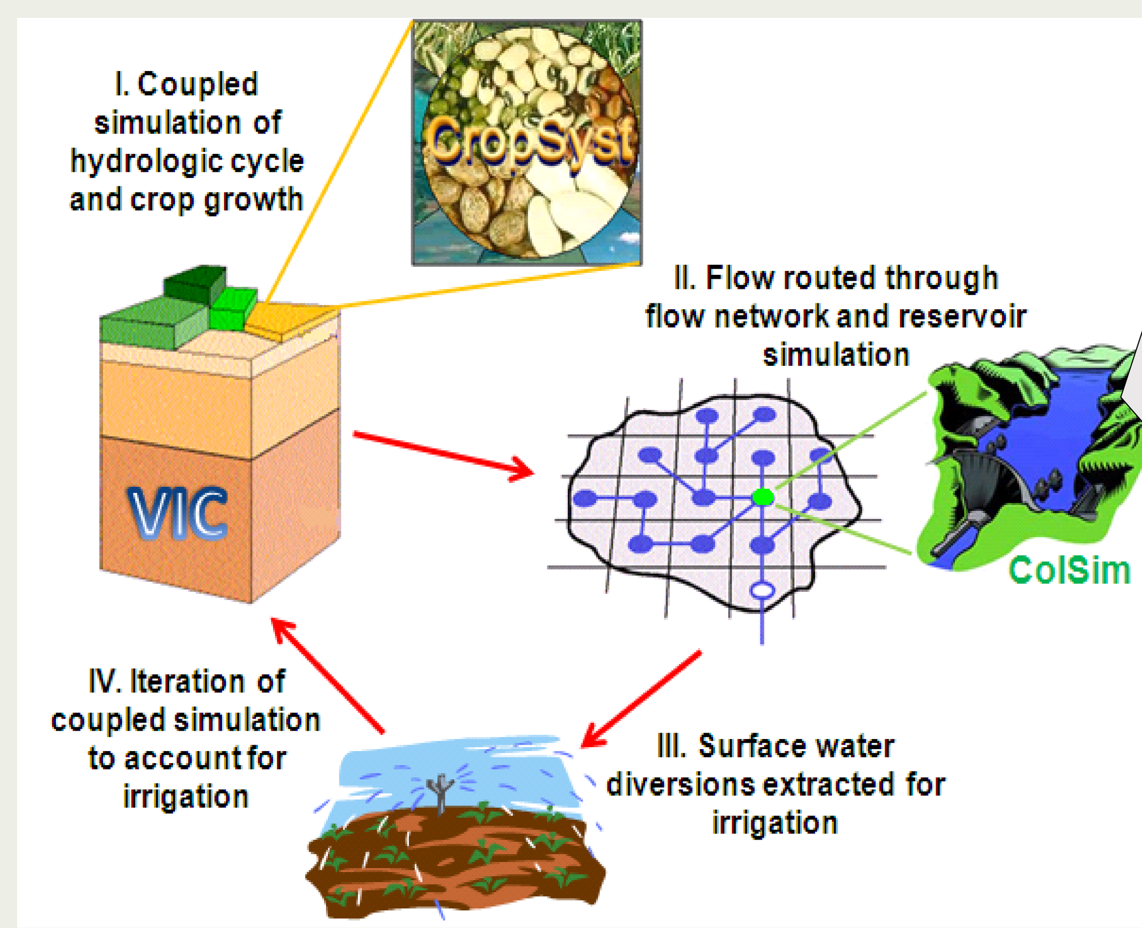


- ❑ Water allocation for irrigation water right holders have been regularly curtailed historically in several parts of the basin. This situation is expected to be exacerbated by climate change.

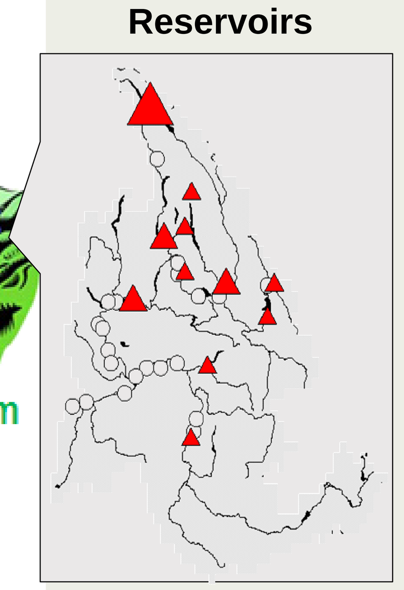
Modeling Framework

- ❑ We applied our newly-developed system of linked models, including the VIC hydrology model (Liang et al. 1994), a dynamic crop systems model (CropSyst: Stockle et al. 2003), reservoir models for the Columbia River Mainstem (ColSim: Hamlet et al. 1999) as well as select tributaries, and an economics model.
- ❑ Irrigation demand and crop yield for each crop type in the basin as well as supply are simulated using VIC-CropSyst, while water management (reservoirs and curtailment) are simulated as a separate process. If curtailment occurs, VIC-CropSyst simulations with reduced irrigation are repeated to examine the effects of curtailment. (Details shown below.)

Biophysical Modeling System



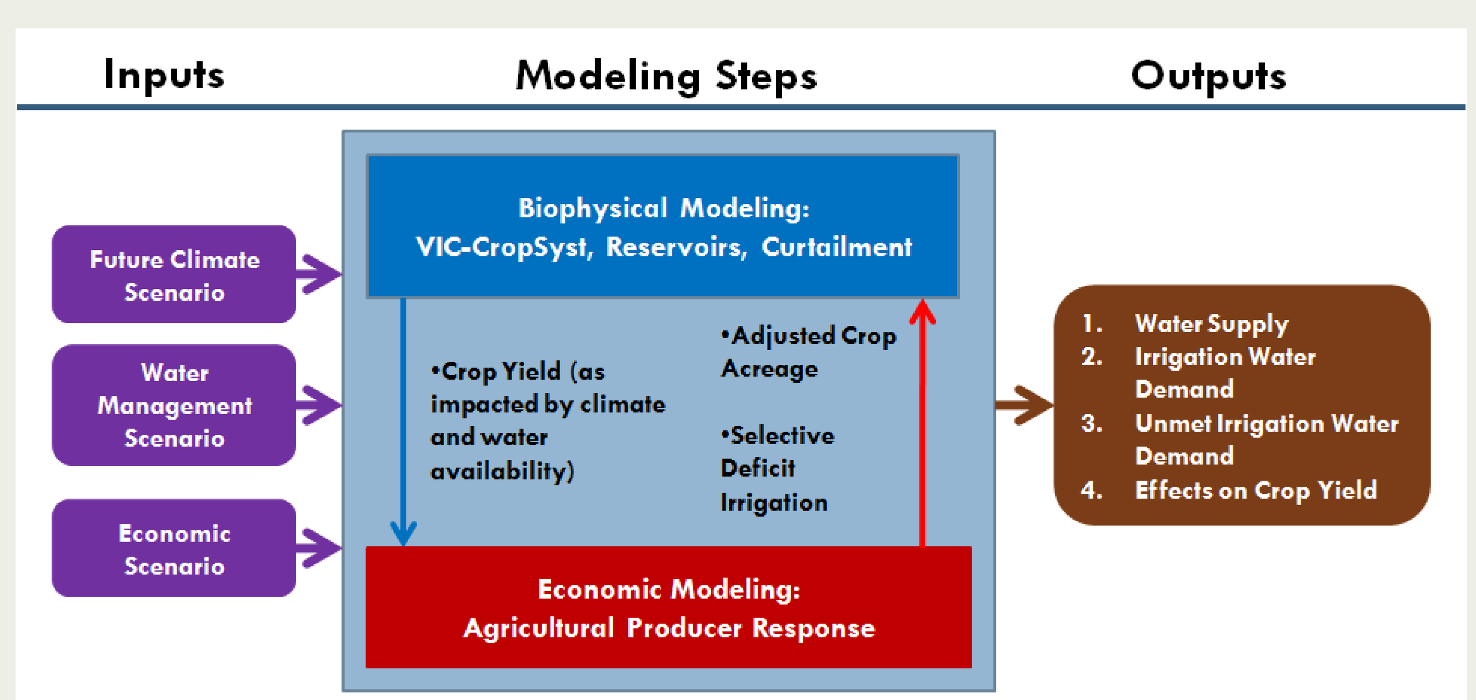
Physical System of Dams and Reservoirs



Economic Model

V. The entire biophysical modeling frame system interacts with the economic model to simulate long term and short term producer response. The long term response is a change in crop mix and the short term response is selective deficit irrigation of crops.

- ❑ This interactive modeling framework is run under three sets of scenarios. (Details shown below.)



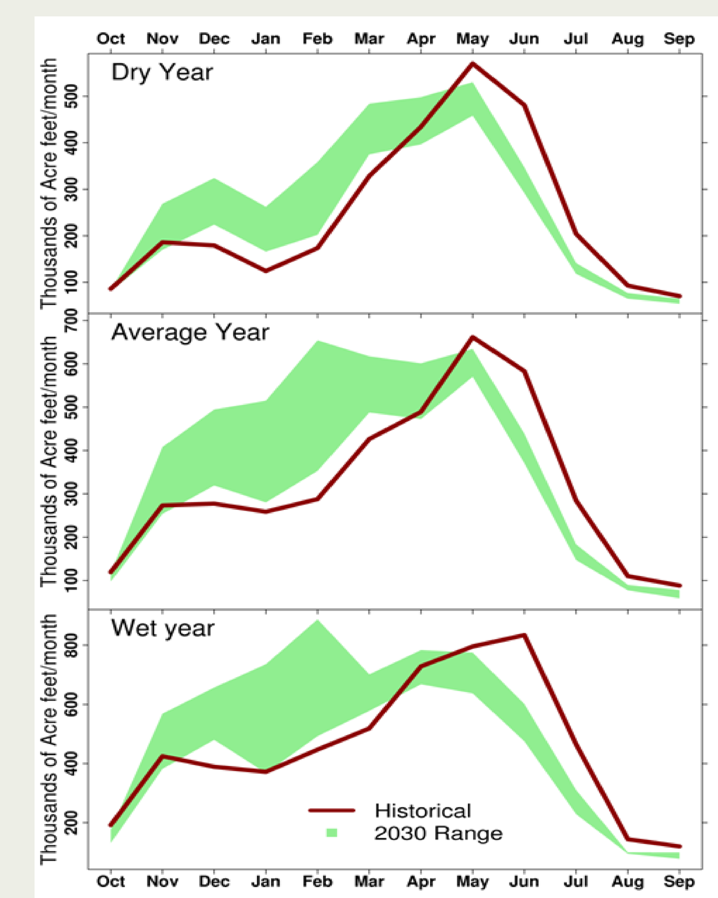
Representative Results

Overall Columbia River Basin Results

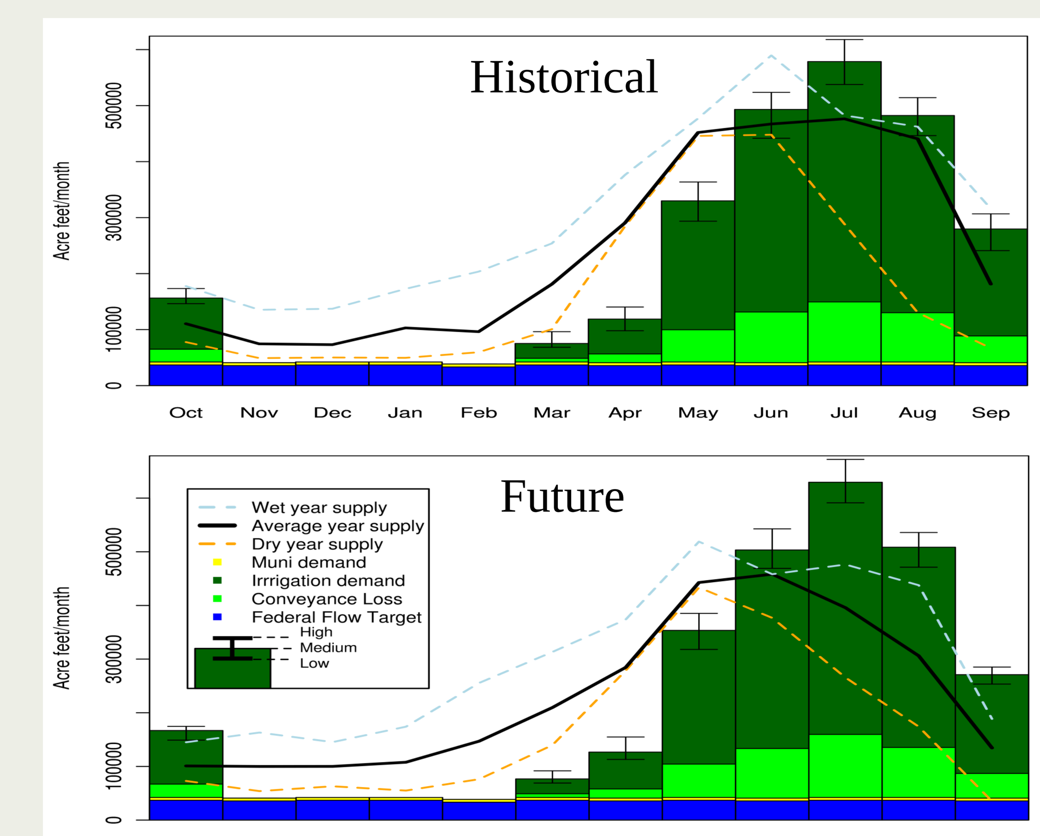
- ❑ A small **increase of around 3.0 (+/-1.2)% in annual surface water supply** at the outlet of the basin in the 2030s.
- ❑ Shift in timing away from the times when demands are highest. (**Decrease in supply of 14.3 (±1.2)% during the irrigation season** and increase of (17.5 (±1.9)% in other seasons.)
- ❑ Irrigation water demand **increases by 3.7%** in the 2030s when accounting for the effects of change in precipitation and temperature alone. When the effects of a change in crop mix due to economics is also factored this **increase is reduced to 1.9%.**

Tributary Watershed Level Results

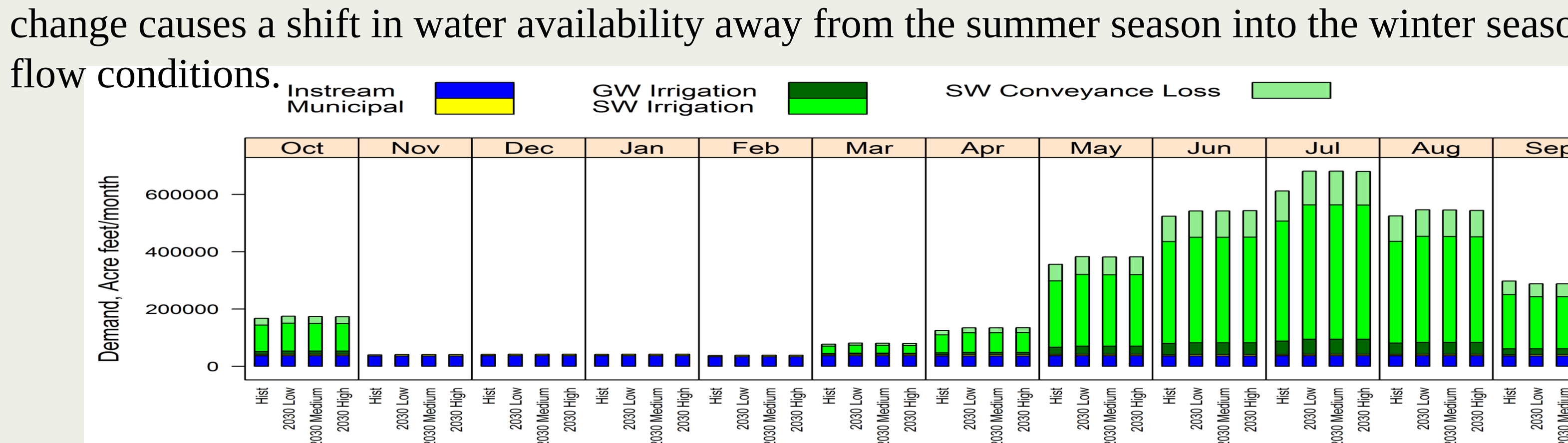
Results for the ***Yakima Watershed*** shown as an example.



Water Supply and Demand (below right). Comparison of surface water supply and demand for historical and future baseline economic scenarios.



Water Supply (above left). Historical ('77-'06) and future unregulated surface water supply for dry, average, and wet (20th, 50th, and 80th percentiles, respectively) year conditions. Climate change causes a shift in water availability away from the summer season into the winter season for all flow conditions.



Water Demand (above). Historical ('77-'06) and future demands for average conditions and three economic scenarios. Irrigation demand increases the most in July.

Conclusions

- ❑ Although future annual surface water supply is associated with larger uncertainty, the seasonality of supply is projected with higher confidence to shift away from the summer irrigation season into the low demand winter season. This is due to some loss of the snowpack and changes in precipitation timing.
- ❑ Irrigation demand is projected to increase in the 2030s. Although reservoir buffering will help manage this to some extent, unmet irrigation demand is expected to increase in tributary watersheds (eg. unmet irrigation demand in the Yakima basin is expected to increase by an average of 50% by 2030), causing increased water stress in an already stressed system.